

SECTION 15971
ELECTRIC CONTROL SYSTEMS
&
FACILITIES MANAGEMENT SYSTEMS

PART 1 - GENERAL

1.1 WORK INCLUDED

- A. Extent of electric control system work required by this section is indicated by drawings and schedules, and by requirements of this section.
 - 1. Control sequences are specified in Division 15 section "Sequence of Operation".
- B. Refer to Division 15 sections for installation of instrument wells, valve bodies, and dampers in mechanical systems.
- C. Installation of Facility Management System (FMS):
 - 1. The FMS Contractor shall furnish and integrate a control system for all mechanical systems and other facility systems, with the existing Facility Management System (FMS) and as included in the project documents. The FMS will provide the functional features as defined in Part 1-General Requirements, Part 2-Products, and Part 3-Execution of these Specifications. The FMS Contractor shall provide a complete and operational system to perform all sequences of operations stated within Section 15985.
 - 2. The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and a web-based operator interface. Depict each mechanical system and building floor plan by a point-and-click graphic. A web server with a network interface card shall gather data from this system and generate web pages accessible through a conventional web browser on each authorized PC connected to the network. Operators shall be able to perform all normal operator functions through the web browser interface.
 - 3. The work under this Section shall include all materials and labor to perform all work required for the installation of the FMS as specified.
 - 4. The drawings and Specifications are complementary to one another—meaning that what is called for on one is to be considered called for in both. Where conflicts exist between the Specifications and/or drawings, the more stringent requirement shall apply.
 - 5. The FMS Contractor shall be responsible for field verification of site conditions and for gathering all necessary field data for all items to be provided under this contract prior to submitting his or her bid.
 - 6. Where work specified under other Sections of this Specification connects to equipment or systems that are listed and described in this Section, the FMS Contractor shall provide proper connection(s) to such equipment, including trade coordination.
- D. Provide all temperature control wiring not shown on the electrical drawings.

1. Temperature control wiring shall be defined as wiring from any device furnished as part of the temperature control system, to the connection point with equipment furnished under other sections, or as required in the sequence of operation.
 2. Provide power wiring to control panels, sensors, actuators, and accessories as necessary.
 3. The term wiring shall include wire conduit, miscellaneous material and labor required for mounting and wiring electrical control devices.
 4. Wiring shall comply with the requirements of Division 16.
- E. Provide the following electrical work as work of this section, complying with requirements of Division 16 sections:
1. All electrical power and control wiring required for the control system that is not specifically shown on the electrical drawings.
- F. Refer to Section 15000 for equipment certification requirements.

1.2 DEFINITIONS

- A. Algorithm: A software procedure for solving a recurrent mathematical or logical problem.
- B. Analog: A continuously varying signal or value (temperature, current, velocity, etc.).
- C. Binary: A two-state system where an "ON" condition is represented by a high signal level and an "OFF" condition is represented by a low signal level.
- D. Facility Management System (FMS): The entire system of hardware and software specifically designed to centrally manage building HVAC and related utilities. The FMS includes the DDC subsystem, open system ports, and open protocol bus or integrators and network routers for connection to information networks.
- E. FMS Contractor: The Facility Management System Contractor responsible for the installation of the Facility Management System specified herein.
- F. Control Process: The software required to perform a complete control loop from input signal to interlock logic, process calculation to final output signal control.
- G. Control Wiring: Includes conduit, wire and wiring devices to install a complete Control System including motor control circuits, interlocks, thermostats, and like devices. Includes all wiring from a DDC cabinet to all sensors and points defined in the Points List summary or specified herein and required to execute the sequence of operation. Includes necessary power wiring to all FMS devices, digital controllers including terminal units and actuators.
- H. Deadband: A temperature range over which no heating or cooling energy is supplied, such as 72-78°F, i.e. as opposed to single point changeover or overlap, or a range from setpoint over which no control action is taken.
- I. Direct Digital Control System: The portion of the FMS which provides closed loop control of all HVAC equipment.

- J. Distributed Control: A system whereby all control processing is decentralized and independent of a central computer. The control system is built up of stand-alone controllers. A single controller failure shall not impact more than one system.
 - K. Integration: The ability of control system components from different manufacturers to connect together and provide coordinated control via real-time data exchange through a common communications data exchange protocol. Integration shall extend to the operator's workstation software, which shall support user interaction with all control system components. Methods of integration include industry standard protocols such as: BACnet, LonMark/LonTalk, ModBus, OLE for Process Control (OPC), or integrator interfaces between cooperating manufacturer's systems.
 - L. Network: A system of distributed control units that are linked together on a communication highway. A network allows sharing of point information between all control units. Additionally, a network provides central monitoring and control of the entire system from any distributed control unit location. First tier networks shall provide "Peer-to-Peer" communications. Second tier networks shall provide either "Peer-to-Peer", Master-Slave or Supervised Token Passing communications.
 - M. Open Protocol Bus (OPB): A pre-programmed communications integrator that allows devices from one manufacturer to communicate and interact with those of another.
 - N. Open System Port (OSP): A user programmable communications port that provides the ability to develop custom communications processes to integrate other operating systems with the FMS System.
 - O. Operator-Machine Interface: A method by which an operator communicates with a FMS System. Operator-machine interfacing allows an operator to command, monitor, and program the system.
 - P. Peripheral: Input/Output equipment used to communicate with the computer and make copies of system outputs, peripherals include CRT, printer, tape deck, diskette, etc.
 - Q. Pick Point: A pick point is a graphical display element that allows the operator to 'click' the item and automatically display the associated screen or service. Any screen may have pick points to or be linked from any other screen. Pick points shall be configured on each display screen to provide a logical user navigation system using a ladder tree hierarchy.
 - R. PID Control Loop: A mathematical calculation used to evaluate a control input and determine the control output value required to maintain the input value at setpoint. The PID (Proportional, Integral, Derivative) control loop shall have operator adjustable maximum rate of change, P and D gains and loop response time delay. The loop shall be self-integrating so that no integral constant is required and the loop shall not be subject to 'Integral Windup'.
 - S. The term 'provide' means 'provide complete in place', that is, furnished and installed and ready for operation and use.
- 1.3 QUALITY ASSURANCE
- A. General:
 - 1. The Facility Management System (FMS) herein specified shall be fully integrated and installed as a complete package by the Facility Management System Contractor. The System shall include all wiring, piping, installation supervision, calibration, adjustments, and checkout necessary for a complete and fully operational system.

2. The Facility Management System Contractor shall be a factory owned branch office or authorized factory representative that is regularly engaged in the engineering, programming, installation and service of Facility Management Systems of similar size and complexity.
3. The FMS Contractor shall be responsible for all work fitting into place in a satisfactory and neat workmanlike manner acceptable to the Owner/Architect/Engineer.
4. The FMS Contractor will coordinate with other Trade Contractors regarding the location and size of pipes, equipment, fixtures, conduit, ducts, openings, switches, outlets, and so forth, in order to eliminate any delays in the progress of the job.

B. Experience Record:

1. The FMS Contractor shall have a minimum of five years experience with the complete, installation of Facility Management Systems of similar size and technical complexity. The FMS Contractor shall provide a list of five comparable projects that have Facility Management Systems with the features as specified for this project. These projects must be on-line and functional.
2. The FMS Contractor shall employ specialists in the field of Facility Management Systems including: Programming, Engineering, Field Supervision, and Installation. Specialists shall have a minimum of five years of experience with Facility Management Systems.

C. Products:

1. The Facility Management System architecture shall consist of the products of a manufacturer regularly engaged in the production of Facility Management Systems, and shall be the manufacturer's latest standard of design. Controllers and DDC (Direct Digital Control) system components shall be current production products.

D. Quality Assurance Program:

1. The FMS Contractor shall implement a Quality Assurance Program. At minimum, this program shall consist of the following requirements:
 - a. The FMS Contractor shall assign a single individual to serve as the Quality Assurance Manager, who is to be responsible for the management of the program.

E. Governing Code & Standards Compliance:

1. The FMS Contractor shall comply with all current governing codes, ordinances, and regulations including UL, NFPA, the local Building Code, NEC, and so forth.
2. IEEE 802.15.4 - IEEE Standard for Information technology - Telecommunications and information exchange between systems--Local and metropolitan area networks-- Specific requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (LR-WPANs)

F. FCC Regulation:

1. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Section 15, Governing Radio Frequency Electromagnetic Interference, and be so labeled.

1.4 COORDINATION

A. Divisions:

1. The FMS Contractor shall cooperate with other divisions performing work on this project as necessary to achieve a complete and neat installation. The Contractor shall also consult the drawings and specifications of all trades to determine the nature and extent of others' work.

B. Contractors, Sub-contractors, Employees:

1. It will be the duty of this Contractor to work in cooperation with other contractors, and with other sub-contractors and employees, rendering assistance and arranging his or her work so that the entire project will be delivered in the best possible condition and in the shortest time.

1.5 SUBMITTALS

A. Shop Drawings, Product Data, and Samples:

1. The FMS Contractor shall submit within 60 days after award, installation drawings and control strategies for review.
2. Each submittal shall have a cover sheet with the following information provided: submittal ID number; date; project name, address, and title; FMS Contractor name, address and phone number; FMS Contractor project manager, quality control manager, and project engineer names and phone numbers.
3. Each submittal shall include the following information:
 - a. FMS riser diagram showing all DDC controllers, operator workstations, network repeaters, and network wiring.
 - b. One-line schematics and system flow diagrams showing the location of all control devices.
 - c. Points list for each DDC controller, including: Tag, Point Type, System Name, Object Name, Expanded ID, Display Units, Controller Type, Address, Cable Destination, Module Type, Terminal ID, Panel, Slot Number, Reference Drawing, and Cable Number.
 - d. Vendor's own written description for each sequence of operations, to include the following:
 - (1) Sequences shall reference input/output and software parameters by name and description.
 - (2) The sequences of operations provided in the submittal by the FMS Contractor shall represent the detailed analysis needed to create actual programming code from the design documents.
 - (3) Points shall be referenced by name, including all software points such as programmable setpoints, range limits, time delays, and so forth.
 - (4) The sequence of operations shall cover normal operation and operation under the various alarm conditions applicable to that system.

- e. Cataloged cut sheets of all equipment used. This includes, but is not limited to, the following: DDC Panels, peripherals, sensors, actuators, dampers, control air system components, and so forth.
 - f. Range and scale information for all transmitters and sensors. This sheet shall clearly indicate one device and any applicable options. Where more than one (1) device to be used is on a single sheet, submit two sheets, individually marked.
 - g. Training course outlines for each four-hour session.
 - h. Hardware data sheets for all operator workstations, local access panels, and portable operator terminals.
 - i. Software manuals for all applications programs to be provided as a part of the operator workstations, portable operator terminals, programming devices, and so forth for evaluation for compliance with the performance requirements of this Specification.
 - j. Initial project team Quality Assurance compliance report.
4. FMS Contractor shall not begin fabrication or field installation until receiving authorization to proceed in the form of an approved submittal. FMS Contractor shall be solely responsible for the removal and replacement of any item not approved by submittal at no cost to the Owner.

1.6 O&M MANUALS

A. Submit three sets of each manual.

- 1. Include the following documentation in the Hardware Manual:
 - a. General description and cut sheets for all components.
 - b. Detailed wiring and installation illustrations and complete calibration procedures for each field and panel device.
 - c. Complete trouble-shooting procedures and guidelines.
 - d. Complete operating instructions for all systems.
 - e. Maintenance Instructions: Document all maintenance and repair/replacement procedures.
- 2. Include the following documentation in the DDC Software Manual:
 - a. Sequence of Operations.
 - b. Program Listing of Software Source Code OR Flow Chart.
 - c. Diagrams of Programming Objects.
 - d. Printed listing of controller and operator workstation database files.
 - e. Software Point Name Abbreviation List.. Include Name, Description, Controller Where Located, Point Type and Point ID.

- f. I/O Point List. Include Point Name, Controller Location, Point Number, Control Device, Range and Span.
 - g. Printouts of all; Reports, Group Listings and Alarm Messages.
 - h. Index of all DDC point names with documentation manual page number references.
- 3. Provide three copies of all manufacturers manuals covering the installed system. This shall include, as a minimum:
 - a. System Engineering Manual.
 - b. System Installation Manual.
 - c. Programming Manual.
 - d. Engineering and Troubleshooting Bulletins.
 - e. Operator Workstation Software Manual.
 - f. All other pertinent manuals published by the control system manufacturer.
- 4. All manuals shall be provided in hard copy format or on a single Compact Disk (CD) as part of an on-line documentation system through the operator workstation.
- 5. Provide complete record drawings of the completed system.

1.7 WARRANTY

A. Material:

- 1. The Control System shall be free from defects in material and workmanship under normal use and service. If within one (1) year from the date of completion any of the equipment herein described is defective in operation, workmanship or materials, it will be replaced, repaired or adjusted at the option of the FMS Contractor free of charge.

B. Installation:

- 1. The Control System shall be free from defects in installation workmanship for a period of one (1) year from acceptance. The FMS Contractor shall respond within 24 hours, and correct any defects in workmanship within one week of request of warranty service by the Owner.
- 2. Control System failures and deficiencies during the warranty period shall be adjusted, repaired, or replaced at no charge or reduction in service to the Owner.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Manufacturer: Subject to compliance with requirements, provide electric control systems of one (1) of the following:

- 1. Honeywell by Engineered Controls, Inc.
- 2. Approved Equal

2.2 MATERIALS AND EQUIPMENT

- A. General: Provide electric control products in sizes and capacities indicated, consisting of sensors, controllers, and other components as required for complete installation. Except as otherwise indicated, provide manufacturer's standard control system components as indicated by published product information, designed and constructed as recommended by manufacturer. Provide electric control systems with the following functional and construction features as indicated.
- B. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by Owner. Spare parts shall be available for at least five years after completion of this contract.
- C. Performance Standards: System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).
 - 1. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 sec.
 - 2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 sec. and shall automatically refresh every 15 sec.
 - 3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
 - 4. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.
 - 5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 15 sec.
 - 6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.
 - 7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
 - 8. Multiple Alarm Annunciation. Each workstation on the network shall receive alarms within 5 sec of other workstations.
- D. Electronic Sensors:
 - 1. Outdoor air sensor shall be of the thermistor (NTC) type with a high resistance change versus temperature change. Sensor shall be available for outdoor or duct mounting. Sensor shall connect to remote controller by means of a two-wire unshielded cable.
- E. Relays:
 - 1. Control Relays: Control relays shall be plug-in type, UL listed, and shall have dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
 - 2. Time Delay Relays: Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable $\pm 100\%$ from setpoint shown. Contact

rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

F. Current Transmitters:

1. AC current transmitters shall be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two-wire output. Full-scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be $\pm 1\%$ full-scale at 500 ohm maximum burden.
2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
3. Unit shall be split-core type for clamp-on installation on existing wiring.

G. Current Transformers:

1. AC current transformers shall be UL/CSA recognized and shall be completely encased (except for terminals) in approved plastic material.
2. Transformers shall be available in various current ratios and shall be selected for $\pm 1\%$ accuracy at 5 A full-scale output.
3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.

H. Voltage Transmitters:

1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.
2. Adjustable full-scale unit ranges shall be 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400-600 Vac. Unit accuracy shall be $\pm 1\%$ full-scale at 500 ohm maximum burden.
3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized at 600 Vac rating.

I. Voltage Transformers:

1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.
2. Transformers shall be suitable for ambient temperatures of 4°C-55°C (40°F-130°F) and shall provide $\pm 0.5\%$ accuracy at 24 Vac and 5 VA load.
3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

J. Central (Master) Control Panels: Provide central control panels of fully-enclosed steel cubical type, with locking doors and/or locking removable backs. Match finish of panels and provide multi-color graphic displays, schematically showing system being controlled.

K. Line voltage to 24V AC transformer shall be supplied as required to provide adequate control voltage to the control system.

2.3 GENERAL PRODUCT DESCRIPTION

- A. The Facility Management System (FMS) shall be capable of integrating multiple building functions, including equipment supervision and control, alarm management, energy management, and trend data collection.
- B. The FMS shall consist of the following:
 - 1. Standalone DDC Panels
 - 2. Standalone Application Specific Controllers (ASCs).
 - 3. Operator's Workstations or Servers.

The system shall be modular in nature, and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, ASCs, and operator devices.

- C. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

2.4 NETWORKING/COMMUNICATIONS

- A. The design of the FMS shall be networked as shown on the attached system configuration drawing. Inherent in the system's design shall be the ability to expand or modify the network either via a local network, auto-dial telephone line modem connections, or a combination of the two networking schemes.
- B. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a unified control network. A gateway (translator) shall communicate with third-party equipment furnished or installed by others.
- C. Install new wiring and network devices as required to provide a complete and workable control network. Use existing Ethernet backbone for network segments marked "existing" on project drawings.
- D. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.
- E. Inter-network operator interface and value passing shall be transparent to inter-network architecture.
 - 1. An operator interface connected to a controller shall allow the operator to interface with each inter-network controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each inter-network controller.
 - 2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the inter-network. Program and test all cross-controller links required to execute control strategies specified in Section 15900 Appendix A. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.
- F. System shall automatically synchronize controller time clocks daily from an operator-designated controller via the inter-network. If applicable, system shall automatically adjust for daylight saving and standard time.
- G. System shall capable of being expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.
- H. Local Network:

1. DDC Panel Support. The DDC Panel shall directly oversee a local network such that communications may be executed directly to and between ASCs.
2. Data Access: All operator devices, either network resident or connected via dial-up modems, shall have the ability to access all point status and application data on the network.
 - a. Access to system data shall not be restricted by the hardware configuration of the facility management system.
3. Global Data Sharing: Global Data Sharing or Global point broadcasting shall allow point data to be shared between ASCs, when it would be inefficient or impractical to locate multiple sensors.
4. General Networking Design: Network design shall include the following provisions:
 - a. Data transfer rates for alarm reporting and quick point status from multiple ASCs. The minimum baud rate shall be 9600 baud.
 - b. Support of any combination of ASCs. A minimum of 100 ASCs shall be supported on a single local network. The bus shall be addressable for up to 256 ACSs.
 - c. Detection of single or multiple failures of ASCs or the network media.
 - d. Error detection, correction and retransmission to guarantee data integrity.
 - e. Commonly available, multiple-sourced, networking components shall be used.
 - f. Use of an industry standard protocol, such as Optomux and IEEE RS-485 communications interface.

2.5 DIGITAL PANELS

- A. General: Digital Panels shall be microprocessor-based, multi-tasking, multi-user, digital control processors.
- B. Memory:
 1. Each Digital Panel shall have sufficient memory to support its own operating system and databases including:
 - a. Control processes.
 - b. Energy Management Applications.
 - c. Alarm Management.
 - d. Trend Data.
 - e. Maintenance Support Applications.
 - f. Operator I/O.
 - g. Dial-up Communications.
 - h. Manual Override Monitoring.
- C. Point types: Each DDC panel shall support the following types of point inputs and outputs.
 1. Digital Inputs for status/alarm contacts.
 2. Digital outputs for on/off equipment control.

3. Analog Inputs for temperature, pressure, humidity, flow, and position measurements.
 4. Analog Outputs for valve and damper position control and capacity control of primary equipment.
 5. Pulse Inputs for pulsed contact monitoring.
- D. Expandability: The system shall be modular in nature, and shall permit easy expansion through the addition of field controllers, sensors, actuators.
- E. Serial Communication Ports: Digital Panels shall provide at least two RS-232C serial data communication ports for simultaneous operation of multiple operator I/O devices, such as laptop computers, personal computers, and video display terminals.
- F. Hardware Override Monitoring: Digital Panels shall monitor the status of all overrides, and include this information in logs and summaries to inform the operator that automatic control has been inhibited.
- G. Local Status Indicator Lamps: The DDC panel shall provide local status indication for each binary input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device.
- H. Integrated Online Diagnostics: Each Digital Panels shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all subsidiary equipment. Digital Panels shall provide both local and remote annunciation of any detected component failures or repeated failure to establish communication. Indication of the diagnostic results shall be provided at each Digital Panel.
- I. Surge and Transient Protection: Isolation shall be provided at all network terminations, as well as all field point terminations, to suppress induced voltage transients consistent with IEEE Standard 587-1980. Isolation levels shall be sufficiently high as to allow all signal wiring to be run in the same conduit as high voltage wiring where acceptable by electrical code.
- J. Environment: Controller hardware shall be suitable for anticipated ambient conditions.
1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29°C to 60°C (-20°F to 140°F).
 2. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
- K. Serviceability:
1. Controllers shall have diagnostic LEDs for power, communication, and processor.
 2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.
- L. Powerfail Restart: In the event of the loss of normal power, there shall be an orderly shutdown of the Digital Panel to prevent the loss of database or operating system software. Nonvolatile memory shall be incorporated for all critical controller configuration data, and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.
1. Upon restoration of normal power, the Digital Panel shall automatically resume full operation without manual intervention.

2. Should Digital Panel memory be lost for any reason, the user shall have the capability of reloading the Digital Panel via the local RS-232C port or local area network.

2.6 SYSTEM SOFTWARE FEATURES

A. General:

1. All necessary software to form a complete operating system, as described in this specification, shall be provided.
2. The software programs specified in this section shall be provided as an integral part of the Digital Panel, and shall not be dependent upon any higher level computer for execution.
3. Operating System: Web server shall have an industry-standard professional-grade operating system. Acceptable systems include Microsoft Windows XP Pro, Red Hat Linux, or Sun Solaris.

B. System Tools: System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand-alone program, software shall be installable on standard IBM-compatible PCs with no limit on the number of copies that can be installed under the system license.

1. A set of all site survey and installation tools as well as software shall be provided to the contractor use for system installation and commissioning for the duration of the warranty period. A set of all site survey and installation tools as well as software shall be provided to the owner for permanent possession for ongoing system maintenance and trouble shooting.
2. Automatic System Database Configuration: Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.
3. Controller Memory Download: Operators shall be able to download memory from the system database to each controller.
4. System Configuration: Operators shall be able to configure the system.
5. Online Help: Context-sensitive online help for each tool shall assist operators in operating and editing the system.
6. Security: System shall require a user name and password to view, edit, add, or delete data.
 - a. Operator Access: Each user name and password combination shall define accessible viewing, editing, adding, and deleting functions in each system application, editor, and object.
 - b. Automatic Log Out: Automatically log out each operator if no keyboard or mouse activity is detected. Operators shall be able to adjust automatic log out delay.
 - c. Encrypted Security Data: Store system security data including operator passwords in an encrypted format such as 128 bit SSL encryption. System shall not display operator passwords.

7. System Diagnostics: System shall automatically monitor controller and I/O point operation. System shall annunciate controller failure and I/O point locking (manual overriding to a fixed value).
8. Alarm Processing: System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as specified in Division 15 Section Sequences of Operation.
9. Alarm Messages: Alarm messages shall use an English language descriptor without acronyms or mnemonics to describe alarm source, location, and nature.
10. Alarm Reactions: Operator shall be able to configure (by object) actions workstation or web server shall initiate on receipt of each alarm. As a minimum, workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.
11. Alarm Maintenance: Operators shall be able to view system alarms and changes of state chronologically, to acknowledge and delete alarms, and to archive closed alarms to the workstation or web server hard disk from each workstation or web browser interface.
12. Trend Configuration: Operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk.
13. Object and Property Status and Control: Operator shall be able to view, and to edit if applicable, the status of each system object and property by menu, on graphics, or through custom programs.
14. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.
15. Standard Reports: Furnish the following standard system reports:
 - a. Objects: System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.
 - b. Alarm Summary: Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.
 - c. Logs: System shall log the following to a database or text file and shall retain data for an adjustable period:
 - (1) Alarm History.
 - (2) Trend Data: Operator shall be able to select trends to be logged.
 - (3) Operator Activity: At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm acknowledgment and deletion. System shall date and time stamp logged activity.

16. Custom Reports: Operator shall be able to create custom reports that retrieve data, including archived trend data, from the system, that analyze data using common algebraic calculations, and that present results in tabular or graphical format. Reports shall be launched from the operator interface.
17. Graphics Generation: Graphically based tools and documentation shall allow Operator to edit system graphics, to create graphics, and to integrate graphics into the system. Operator shall be able to add analog and binary values, dynamic text, static text, and animation files to a background graphic using a mouse.
18. Graphics Library: Complete library of standard HVAC equipment graphics shall include equipment such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. Library shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. Library graphic file format shall be compatible with graphics generation tools.
19. Custom Application Programming: Operator shall be able to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:
 - a. Language: Language shall be graphically based and shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks.
 - b. Programming Environment: Tool shall provide a full-screen, cursor-and-mouse-driven programming environment that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming code, and to copy blocks of code to a file library for reuse in other control programs.
 - c. Independent Program Modules: Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.
 - d. Debugging and Simulation: Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step's time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax and for execution errors.
 - e. Conditional Statements: Operator shall be able to program conditional logic using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
 - f. Mathematical Functions: Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.
 - g. Variables: Operator shall be able to use variable values in program conditional statements and mathematical functions.
 - (1) Time Variables: Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other

predefined variables or simple control logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.

- (2) System Variables: Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software as described in Controller Software section.

C. Control Software Description:

1. Equipment Cycling Protection: Control software shall include a provision for limiting the number of times each piece of equipment may be cycled within any one-hour period.
2. Heavy Equipment Delays: The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.
3. Powerfail Motor Restart: Upon the resumption of normal power, the DDC panel shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling, and turn equipment on or off as necessary to resume normal operation.

D. Energy Management Applications: Building and energy management application software shall reside and operate in DDC Panels. Applications shall be editable through operator workstation, web browser interface, or engineering workstation. DDC Panels shall have the ability to perform any or all of the following energy management routines:

1. Time of Day Scheduling.
2. Calendar Based Scheduling.
3. Holiday Scheduling.
4. Optimal Start.
5. Optimal Stop.
6. Demand Limiting.
7. Load Rolling.
8. Heating/Cooling Interlock.
9. Average/High/Low Signal Select and Reset.

E. All programs shall be executed automatically without the need for operator intervention, and shall be flexible enough to allow user customization. Programs shall be applied to building equipment described in the "Execution" portion of this specification.

F. Programming Capability: Digital Panels shall be able to execute configured processes defined by the user to automatically perform calculations and control routines.

1. Process Inputs and Variables: It shall be possible to use any of the following in a configured process:
 - a. Any system-measured point data or status.
 - b. Any calculated data.
 - c. Any results from other processes.
 - d. Boolean logic operators (and, or).
2. Process Triggers: Configured processes may be triggered based on any combination of the following:

- a. Time of day.
 - b. Calendar Date.
 - c. Other processes.
 - d. Events (e.g., point alarms).
3. Data Access: A single process shall be able to incorporate measured or calculated data from any and all other ASCs on the local network.
- G. Pre-Tested Control Algorithms: DDC Panels shall have the ability to perform the following pre-tested control algorithms:
 1. Two Position Control.
 2. Proportional Control.
 3. Proportional plus Integral Control.
 4. Proportional, Integral, plus Derivative Control.
 5. Automatic Control Loop Tuning.
- H. Runtime Totalization: Digital Panels shall automatically accumulate and store runtime hours for binary input and output points specified in the "Execution" portion of this specification.
 1. The Totalization routine shall have a sampling resolution of one minute.
 2. The user shall have the ability to define a warning limit for Runtime Totalization. Unique, user-specified messages shall be generated when the limit is reached.
- I. Pulse Totalization: Digital Panels shall automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for user-selected binary pulse input-type points.
 1. The Totalization routine shall provide calculations and storage accumulations of up to 9,999,999 units (e.g. KWH, gallons, KBTU, ton, etc.).
 2. The Totalization routine shall have a sampling resolution of one minute.
 3. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.
 4. The information available from the Pulse Totalization shall include, but not be limited to, the following:
 - a. Peak demand, with date and time stamp.
 - b. 24-hour demand log.
 - c. Accumulated KWH for day.
 - d. Sunday through Saturday KWH usage.
 - e. Sunday through Saturday Demand KW.
 - f. Demand KW annual history for past 12 periods.
 - g. KWH annual history for past 12 periods.
- J. Event Totalization: Digital Panels shall have the ability to count events, such as the number of times a pump or fan system is cycled on and off.
 1. The Event Totalization feature shall be able to store the records associated with a minimum of 9,999,999 events before reset.

2. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

2.7 APPLICATION SPECIFIC CONTROLLERS - HVAC APPLICATIONS

- A. Each Digital Panel shall be able to extend its monitoring and control through the use of standalone Application Specific Controllers (ASCs).
- B. Each ASC shall operate as a standalone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each ASC shall be a microprocessor-based, multi-tasking, real-time digital control processor.
- C. Each ASC shall have sufficient memory to support its own operating system and databases including:
 1. Control Processes.
 2. Energy Management Applications.
 3. Operator I/O (Portable Service Terminal).
- D. The operator interface to any ASC point data or programs shall be through the Digital Panel or portable operator's terminal connected to any ASC on the network.
- E. ASCs shall directly support the temporary use of a portable service terminal that can be connected to the ASC via zone temperature or directly at the controller. The capabilities of the portable service terminal shall include, but not be limited to, the following:
 1. Display temperatures.
 2. Display status.
 3. Display setpoints.
 4. Display control parameters.
 5. Override binary output control.
 6. Override analog setpoints.
 7. Modification of gain and offset constants.
- F. Powerfail Protection: All system setpoints, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the ASC.
- G. Application Descriptions:

2.8 OPERATOR INTERFACE

- A. Operator shall interface with control system through existing FMS.

2.9 ASSOCIATE EQUIPMENT

- A. Reporting Accuracy: System shall report values with minimum end-to-end accuracy listed in Table 1.
- B. Control Stability and Accuracy: Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.

Table 1
Reporting Accuracy

Measured Variable	Reported Accuracy
-------------------	-------------------

Space Temperature	±0.3°F
Outside Air	±1 °F

C. Temperature Sensors

1. Housing and mounting shall be suitable for the application and room finish.
2. Accuracy: See Table 1 above
3. Sensing element:
Thermistor.
Balco.
Platinum RTD (100 ohms) (1000 ohms).
Solid State.
4. Range:
35°F to 140°F Room.
-60°F to 140°F Outside Air.
5. Room Sensor:
Wall mount with setpoint and/or override flush mount.

2.10 PROJECT RECORDS

- A. Complete project records describing the individual component operation, system operation, and specific application, shall be provided at job completion. Project records shall provide complete and detailed step-by-step operating instructions.
- B. As-built installation drawings shall be provided, indicating the mechanical and electrical equipment connected to the environmental control system.
- C. During job acceptance, the contractor shall provide complete training of building personnel, utilizing the project records outlined.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions under which electric control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.
- B. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Architect or Engineer for resolution before starting rough-in work.
- C. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Engineer for resolution before starting rough-in work.
- D. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to Engineer and obtain written instructions for changes necessary to accommodate Section 15900 work with work of others. Controls Contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.2 PROTECTION

- A. Controls Contractor shall protect against and be liable for damage to work and to material caused by Contractor's work or employees.
- B. Controls Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 COORDINATION

- A. Site:
 - 1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades. If installation without coordination causes interference with work of other trades, Contractor shall correct conditions without extra charge.
 - 2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.
- B. Submittals. See Section 15900 Article 1.10 (Submittals):
- C. Coordination with Other Controls: Integrate with and coordinate controls and control devices furnished or installed by others as follows.
 - 1. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
 - 2. Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

3.4 INSTALLATION OF ELECTRIC CONTROL SYSTEMS

- A. General: Install system and materials in accordance with manufacturer's instructions and roughing-in drawings, and details on drawings. Install electrical components and use electrical products complying with requirements of applicable Division 16 sections of these specifications. Mount controllers at convenient locations and heights.
- B. Control Wiring: The term "control wiring" is defined to include providing of wire, conduit and miscellaneous materials as required for mounting and connecting electric control devices from the control device to its point of connection with other devices. Wiring shown in the electrical plans shall be part of Division 16.
 - 1. The control equipment and connecting wiring should be installed in neat and workmanlike manner. All wiring and conduit shall be run parallel to or at right angles to the building structure, and shall be concealed in finished spaces. Conduit may be run exposed in mechanical rooms or in an area where other piping is exposed.
 - 2. Wiring shall be run in adequately supported rigid raceway, EMT pipe or duct. Wiring in equipment rooms shall be in one of the metal containers mentioned above, run to within one foot of the final connection. The final connection shall be made with exposed wiring. These wires shall be protected by a suitable protective grommet and the end of the metal container shall be securely fastened.

3. Class 2 wiring may be used above drop ceilings and in other concealed but accessible locations provided that it is run parallel to or at right angles to the structure, properly supported and installed in a neat and workmanlike manner. Jacketed harnesses may be used where a number of wires are run together.
 4. Wiring that is in return air plenums shall be teflon protected or some other type of UL approved plenum cable.
- C. Wiring System: Install complete wiring system for electric control systems. Conceal wiring, except in mechanical rooms and areas where other conduit and piping are exposed. Provide multi-conductor instrument harness (bundle) in place of single conductors where number of conductors can be run along common path. Fasten flexible conductors bridging cabinets and doors, neatly along hinge side, and protect against abrasion. Tie and support conductors neatly.
 - D. Number-code or color-code conductors for future identification and servicing of control system.
 - E. Reset Limit Controls: Install manual-reset limit controls to be independent of power controllers; automatic duct heater resets may, at Contractor's option, be installed in interlock circuit of power controllers.
 - F. Unit-Mounted Equipment: Where control devices are indicated to be unit-mounted, ship electric relays, electric switches, valves, dampers, and damper motors to unit manufacturer for mounting and wiring at factory.

3.5 HVAC CONTROL SYSTEM

A. Wiring

1. All conduit, wiring, accessories and wiring connections required for the installation of the Facility Management System, as herein specified, shall be provided by the FMS Contractor unless specifically shown on the Electrical Drawings under Division 16 Electrical. All wiring shall comply with the requirements of applicable portions of Division 16 and all local and national electric codes, unless specified otherwise in this section.
2. All system input wiring shall be twisted shielded pair, minimum 18-gage wire. All system analog output wiring shall be twisted shielded pair/3-wire as required, minimum 18-gage wire. Preconfigured cables between Terminal Unit Controllers and Thermostats are acceptable, minimum 24-gage.
3. All internal panel device wiring for binary outputs and pilot relay shall be minimum 16-gage wire.
4. All Class 2 (24VAC or less) wiring shall be installed in conduit unless otherwise specified.
 - a. Class 2 wiring not installed in conduit shall be plenum rated supported every 5 feet from the building structure utilizing metal hangers designed for this application. Wiring shall be installed parallel to the building structural lines. All wiring shall be installed in accordance with local code requirements. Exposed wiring shall only be allowed in concealed accessible locations.
5. Low voltage control wiring and 24VAC can be run in the same conduit. Power wiring 120VAC and greater must be in a separate conduit.

6. All wiring in mechanical rooms shall be in conduit. Minimum control wiring conduit size 3/4-inch.

B. Identification Standards:

1. Panel Identification. All local control panels shall be identified by a plastic engraved nameplate securely fastened to the outside of the controller enclosure.
2. Wire Identification. All low and line voltage control wiring shall be identified by a number, as referenced to the associated control diagram, at each end of the conductor or cable. Identification number shall be permanently secured to the conductor or cable and shall be typed.

C. Digital Controller Systems:

1. Each system will be provided with its own dedicated direct digital controller or application specific controller. Mechanical systems such as AHUs, VAVs or Packaged system shall not be controlled from more than 1 application specific controller.
2. Systems that use second tier controllers as point expansion for system controllers shall only be allowed when the I/O points are directly controlled by the CPU of the local application specific controller.

D. Input Devices:

1. All Input devices shall be installed per the manufacturers recommendation. The mechanical contractor shall install all in-line devices such as temperature wells, pressure taps, duct smoke detectors, air flow stations, etc.
 - a. Outside Air Sensors: Outside air sensors shall be mounted on the North wall to minimize solar radiant heat impact or located in a continuous intake flow adequate to monitor outside air temperatures accurately. Sensors exposed to solar radiation must be installed with solar shields. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate surrounding the sensor element.
 - b. Space Temperature Sensors: Shall be mounted at 60 inches above the finished floor. Temperature sensors installed in public areas shall be provided with lockable covers to prevent tampering.

3.6 PROGRAMMING

- A. Point Naming: Name points as shown on the equipment points list provided with each sequence of operation in Section 15985. If character limitations make it advisable to shorten the name Owner standards, if available, shall govern. When a single workstation or server serves more than one building, a consistent naming scheme shall be used for each building. Final room numbers shall match those provided by the Owner.
- B. Software Programming: Programming shall provide actions for each possible situation. Graphic- or parameter-based programs shall be documented. Text-based programs shall be modular, structured, and commented to clearly describe each section of the program.
 1. Application Programming: Provide application programming that adheres to sequences of operation specified in Section 15985. Program documentation or comment statements shall reflect language used in sequences of operation.
 2. System Programming: Provide system programming necessary for system operation.

C. Operator Interface:

1. Standard Graphics: Provide graphics as specified in this section above entitled System Graphics. Show on each equipment graphic input and output points and relevant calculated points such as indicated on the applicable Points List in Section 15985. Point information on graphics shall dynamically update.
2. Install, initialize, start up, and troubleshoot operator interface software and functions (including operating system software, operator interface database, and third-party software installation and integration required for successful operator interface operation).

D. Testing Documentation, Demonstration, and Acceptance :

1. Prior to acceptance testing, FMS Contractor shall create, on an individual system basis, trend logs of input and output points, or have an automatic Point History feature for documentation purposes.

E. Demonstration: Prior to acceptance, perform the following performance tests to demonstrate system operation and compliance with specification after and in addition to tests specified in Article 3.17 (Control System Checkout and Testing). Provide Engineer with log documenting completion of startup tests.

1. Engineer will be present to observe and review system demonstration. Notify Engineer at least 10 days before system demonstration begins.
2. Demonstration shall follow process submitted and approved under Section "Submittals". Complete approved checklists and forms for each system as part of system demonstration.
3. Demonstrate actual field operation of each sequence of operation as specified in Division 15, Sequence of Operation. Provide at least two persons equipped with two-way communication. Demonstrate calibration and response of any input and output points requested by Engineer. Provide and operate test equipment required to prove proper system operation.
4. Demonstrate compliance with Section entitled "System Performance".
5. Demonstrate compliance with sequences of operation through each operational mode.
6. Demonstrate complete operation of operator interface.
7. Demonstrate each of the following:
 - a. DDC loop response: Supply graphical trend data output showing each DDC loop's response to a setpoint change representing an actuator position change of at least 25% of full range. Trend sampling rate shall be from 10 seconds to 3 minutes, depending on loop speed. Each sample's trend data shall show setpoint, actuator position, and controlled variable values. Engineer will require further tuning of each loop that displays unreasonably under- or over-damped control.
 - b. Demand limiting: Supply trend data output showing demand-limiting algorithm action. Trend data shall document action sampled each minute over at least a 30-minute period and shall show building kW, demand-limiting setpoint, and status of setpoints and other affected equipment parameters.
 - c. Building fire alarm system interface.

- d. Trend logs for each system: Trend data shall indicate setpoints, operating points, valve positions, and other data as specified in the points list provided with each sequence of operation in Section 15900 Appendix A. Each log shall cover three 48-hour periods and shall have a sample frequency not less than 10 minutes or as specified on its points list. Logs shall be accessible through system's operator interface and shall be retrievable for use in other software programs as specified above in "Trend Configuration".

- 8. Tests that fail to demonstrate proper system operation shall be repeated after Contractor makes necessary repairs or revisions to hardware or software to successfully complete each test.

F. Acceptance:

- 1. After tests described in this specification are performed to the satisfaction of both Engineer and Owner, Engineer will accept control system as meeting completion requirements. Engineer may exempt tests from completion requirements that cannot be performed due to circumstances beyond Contractor's control. Engineer will provide written statement of each exempted test. Exempted tests shall be performed as part of warranty.
- 2. System shall not be accepted until completed demonstration forms and checklists are submitted and approved as required herein, see Section "Submittals".

G. Noncompliant Items:

- 1. The Contractor shall remove and replace, at its expense, all items that are not in compliance with the Specification requirements.

3.2 DYNAMIC ANIMATED COLOR GRAPHIC DISPLAYS

- G. Color graphic floor plan displays, and system schematics for each piece of mechanical equipment (including fans, and so forth) shall be provided, as specified in the point list portion of this Specification, in order to optimize system performance analysis, speed alarm recognition, and simplify user interaction. The FMS Contractor shall fully configure the color graphics and plot all associated control/monitoring points on the screen. Copies of all color graphics screens shall be provided as color printouts to the engineer for approval.

H. System Selection/Penetration:

- 1. The operator interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection, or test-based commands. Floor plans shall display room numbers and each zone shall be color-coded. The operator shall be able to point and click on a room or zone of rooms (in the case of an air handler that serves more than one zone). The room or zone will display an animated flow diagram of the mechanical equipment that serves that zone, with all control and monitoring points associated with that piece of equipment, including setpoints. Setpoints shall be overridden or modified from this screen.

I. Dynamic Animated Data Displays:

- 1. Dynamic temperature values, humidity values, flow values, and status indication shall be shown in their actual respective locations, and shall automatically update to represent current conditions without operator intervention. Damper and valve positions, air and water flow shall be animated and shall represent actual, current conditions.

J. Windowing:

1. The windowing environment of the PC Operator Workstation shall allow the user to simultaneously view several graphics at the same time to analyze total building operation, or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.

K. Alarm Annunciation:

1. Any point in a state of alarm shall change the color of its symbol to red until it is no longer in alarm.

3.3 ADJUSTING AND CLEANING

G. Start-Up: Start-up, test, and adjust electric control systems in presence of manufacturer's authorized representative. Demonstrate compliance with requirements. Replace damaged or malfunctioning controls and equipment.

H. Cleaning: Clean factory-finished surfaces. Repair any marred or scratched surfaces with manufacturer's touch-up paint.

I. Final Adjustment: After completion of installation, adjust thermostats, control valves, motors and similar equipment provided as work of this section.

1. Final adjustment shall be performed by specially trained personnel in direct employ of primary temperature control contractor.

3.4 CLOSEOUT PROCEDURES

G. Owner's Instructions: Provide services of manufacturer's technical representative for one 8-hour day to instruct Owner's personnel in operation and maintenance of electric control systems.

1. Schedule instruction with Owner, provide at least 7-day notice to Contractor and Engineer of training date.

END OF SECTION